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1999 December 6 2000 January 7 document Near-infrared emission-line galaxies in the Hubble Deep Field North

Fumihide Iwamuro, Kentaro Motohara, Toshinori Maihara, Jun'ichi Iwai, Hirohisa Tanabe, Tomoyuki Taguchi, Ryuji Hata, Hiroshi Terada, and Miwa Goto *Department of Physics, Kyoto University, Kitashirakawa, Kyoto 606-8502 E-mail(FI): iwamuro@cr.scphys.kyoto-u.ac.jp* [6pt] Shin Oya *Communications Research Laboratory, Koganei, Tokyo 184-8975* [6pt] Masanori Iye, Michitoshi Yoshida, and Hiroshi Karoji *Optical and Infrared Astronomy Division, National Astronomical Observatory, Mitaka, Tokyo 181-8588* and Ryusuke Ogasawara, and Kazuhiro Sekiguchi *Subaru Telescope, National Astronomical Observatory, 650 North Aohoku Place, Hilo, HI 96720, USA* We present the 2.12 μm narrow-band image of the Hubble Deep Field North taken with the near-infrared camera (CISCO) on the Subaru telescope. Among five targets whose H α or [O iii] emission lines are redshifted into our narrow-band range expected from their spectroscopic redshift, four of them have strong emission lines, especially for the two [O iii] emission-line objects. The remaining one target shows no H α emission in spite of its bright rest-UV luminosity, indicating that this object is already under the post-starburst phase. The volume-averaged *SFR* derived from the detected two H α emission is roughly consistent with that evaluated from the rest-UV continuum.

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headings

Introduction The Hubble Deep Field North (HDF-N) has been the deepest and the most scrutinizingly observed area since the first images taken by WFPC2 (Williams et al. 1996). The acquired data dramatically pushed the study of the global star-formation history of the early Universe with the establishment of the technique to determine the photometric redshift. The volume-averaged star-formation rate (*SFR*) derived from UV-to-optical data in this field shows a declination from the peak at $z \simeq 1.5$ toward the higher- z (Madau et al. 1996), while there are some suggestions that the *SFR* remains almost at a constant value when the reddening correction (Calzetti 1998; Steidel et al. 1999) or the selection effect of the rest-UV surface brightness (Pascarelle et al. 1998) is taken into account. On the other hand, the volume-averaged *SFR* derived from the H α luminosity density tends to be larger than that evaluated from the rest-UV continuum (Pettini et al. 1998; Glazebrook et al. 1999; Yan et al. 1999), possibly due to a difference in the reddening effect between the UV continuum and the H α emission line.

Now, the HDF-N has become a standard area for studying distant galaxies, and various catalogs are available (Fernández-Soto et al. 1999; Thompson et al. 1999; etc.). In this paper, we report on the results of the observation of the HDF-N by the near-infrared camera CISCO mounted on the Subaru telescope. This observation was planned not only for verifying the system performance in the engineering phase just after the first light observing run, but also for studying the H α or [O iii] luminosity density in this field. The details of the observation and the data reduction are described in section 2, the detection of the near-infrared emission-line objects and the numerical results are reported in section 3, and the properties of these objects and the volume-averaged star-formation rate are discussed in section 4. Throughout this paper, we assume the Hubble constant of $H_0 = 50 \text{ km s}^{-1} \text{ Mpc}^{-1}$ and the deceleration parameter of $q_0 = 0.5$.

Observations and Data Reduction Observations of the HDF-N were made at the Subaru telescope on 1999 February 23, 25, and 27 with the Cooled Infrared Spectrograph and Camera for OHS (CISCO; Motohara et al. 1998). The field was imaged through a standard K' (1.96–2.30 μm) and H $_2$ 1–0 S(1) (2.110–2.130 μm , hereafter $N212$) filters. Within the $2' \times 2'$ field-of-view of the CISCO, there are five candidates whose rest-frame optical emission lines are redshifted into the bandpass of the $N212$ filter on the basis of their spectroscopic redshifts. and several more candidates expected similarly from their photometric redshifts (Fernández-Soto et al. 1999 and references therein). The images were taken using an octagonal-star-like dither pattern with a diameter of $12''$. In the K' -band case, 20×12 sequential exposures were made at each position (60×6 in the case of $N212$), yielding a total exposure time of 1920 s for the standard round of the observation. Unfortunately, the seeing size was unstable during this observing run, and varied from $0.-2pt''4$ to $0.-2pt''9$ in each set of exposures. The observations are summarized in table 1.

All image reductions were carried out using IRAF. The initial reduction to make a “quick look image” followed that of standard infrared-image processing: a flat fielding using the “standard K' sky flat”, median-sky subtraction, and shift-and-add to combine the image. Then, the positions of the bright sources were listed in a “mask table” and the median-sky image was reconstructed by masking out the listed bright

objects. In the K' -band case, the median smoothed sky image was also used as the self-sky-flat image, and all images were re-flattened by this frame. After applying secondary self-sky flat fielding and sky subtraction, the following reduction processes were carried out: a bad-pixel correction, self-fitting to remove any minor residual of the bias pattern with masking the listed bright object, and shift-and-add of all images with a 3σ clipping algorithm. The reduced K' and $N212$ images are shown in figure 1. The effective exposure times are equal to the total exposure time of 5280 s in the K' - and 9360 s in the $N212$ -band, respectively, because there was no discarded frame. The FWHMs for the point source in the final images are $0.-2pt''58$ (K') and $0.-2pt''67$ ($N212$).

Results After a Gaussian smoothing was applied to the K' image to make the image size identical to that of the $N212$ image, object detection was performed on each frame using SExtractor (Bertin, Arnouts 1996). We employed the “BEST” (Kron-like) magnitude output as the total magnitude, while the $N212-K'$ color within $1.-2pt''16$ ϕ (10 pix) aperture was measured by running SExtractor in the *double-image mode*: K' magnitudes for the $N212$ selected sample were derived using the $N212$ frame as a reference image for detection and the K' image for measurements only and *vice versa* for the K' selected sample. Next, each catalog was compared with the redshift catalog of Fernández-Soto et al. (1999) under the condition that the nearest corresponding pair having the position difference smaller than $0.-2pt''9$ is regarded as the same object. The size of the effective area is 3 arcmin² and the distribution of the identified objects is shown in figure 2.

The identified and unidentified objects are plotted on the $N212-K'$ color versus $N212$ magnitude diagram (figure 3) together with the simulated data of the artificial point sources whose intrinsic $N212-K'$ colors are 0 mag. Here, the horizontal $N212$ mag is the aperture magnitude, because the scatter of the simulated data becomes smaller than in the case when the total magnitude is applied. The 98% confidence level estimated from the simulated data points is expressed as equation $N212-K'=2.5 \log(1 \pm 10^{\frac{-21.45}{2.5}})$,